LBNE 35 Ton Prototype Muon Telescope Crossing Rate and Ratio

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Purpose

The LBNE 35 Ton Prototype is an experiment designed to address several of the questions regarding the potential behavior of the projected LBNE near detector, some of which are related to its immense size. Because of the impracticality of maintaining only a single set of wire planes in the real detector's TPC, multiple chambers must be created within for data collection. As a result, some area insensitive to crossing particles will be created within the detector. Understanding how crossing cosmic muon signals appear in light of this dead area is an important aspect of the project, and has become one of the aims of the 35 Ton Prototype.

Scintillation counters placed outside the TPC serve the purpose of marking the time frames during which to search for ionizations caused by these muons, and will thus permit analysis of the muon tracks through the lens of a TPC with area insensitive to data collection. Spacial constraints for the 35 Ton Prototype cause the most practical method of observing muons to involve two planes of counters above the TPC, as shown in Figure One. Because of this restriction, we will not be able to measure with certainty that a muon has crossed through the TPC if it crosses through the counters. By adjusting the apparatus dimensions, we change the ratio between muons crossing the counters and the TPC's top and bottom, and those muons crossing just the two counters. Optimizing this ratio serves the purpose of reducing the quantity of blank data sets acquired when searching for those that include the desired muon tracks. This is one of our goals.

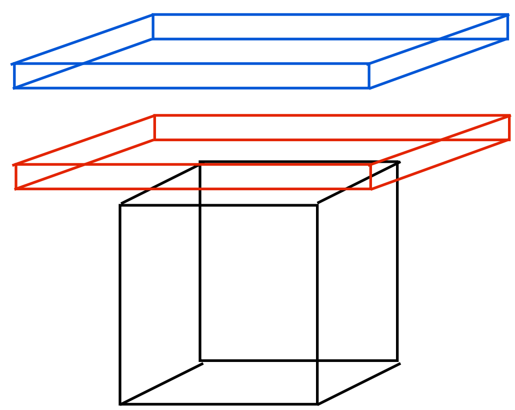

Figure One: LBNE 35 Ton Muon Counter Diagram (not to scale)

Another goal is to display the relationship between this ratio and the rate of muons that cross through the two counter planes. An ideal ratio is high, and an ideal rate is high enough so that muons pass frequently enough to use in analysis.

In our efforts to ensure that the counters register a muon only when a muon actually crosses, we also intend to compare the muon rates through two counter configurations: one where the top counter plane consists of one layer of BSU counters, and another where the top plane consists of two layers of BSU counters. Whether or not the rates through these two apparatuses differ significantly determines whether we employ one layer or multiple layers of counters in coincidence per plane in the 35 Ton Prototype near detector.

Process

A theoretical muon rate through the two counters was calculated using methods described in "Flux Calculation for Muon Trigger" (LArTPC Document 1008-v1). The ratio of those muons passing through the TPC and counters to those just passing through the counters was approximated by a program that creates random muon paths through the counters and extends those paths to the depths of the TPC top and bottom. It then evaluates whether the muon actually crossed the TPC's top and bottom, and evaluates the ratio.

To determine if using multiple layers of counters in coincidence for each plane would be advantageous, we constructed a counter configuration as shown in Figure Two. The top and bottom planes are comprised of eight parallel BSU counters, and the top plane also has a second layer of eight counters resting directly on the first. We then recorded the muon rate through the two planes, at first only using the top layer of counters in the top plane. Afterward, we set each counter in the top plane in coincidence with the counter in the layer below it, and demanded that a logic "and" must be made between them. We then recorded the rate through the two planes of counters under these conditions.

Figure Two: Counter Plane Configuration

In both cases, a logic exclusive "or" was employed between the counters of each of the two planes. The entire process was then repeated for a normal "or". Both logic modes were used so that we could compare the measured rate with the theoretical rate under several conditions and ensure that each measured quantity reasonably reflected the calculated value.

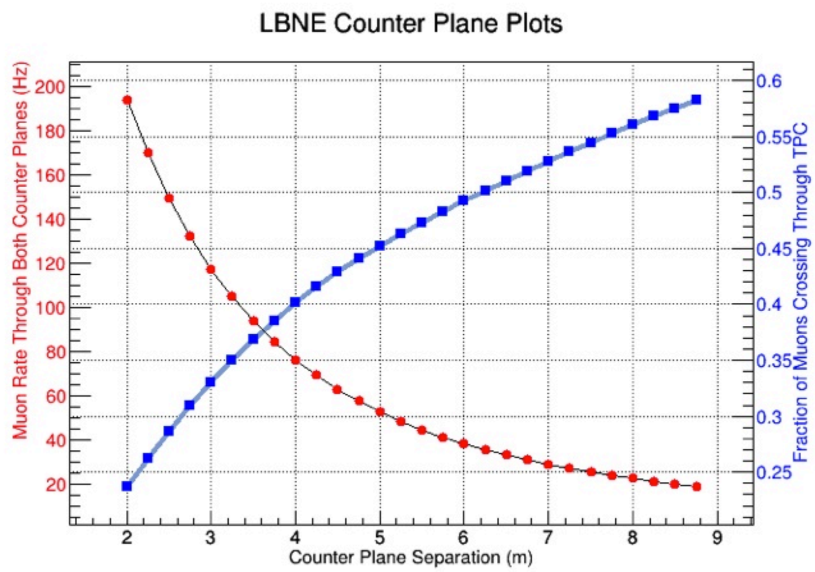

Figure Three: Muon Rate vs. Ratio for 35 Ton Prototype

Results

With an initial estimate of the area available for the counter planes above the TPC, the muon rate through the two counters and the ratio of TPC-crossing muons to non-TPC-crossing muons are plotted as a function of the distance

Top Coincidence?	Exclusive Or?	Rate (Hz)	Rate Error (Hz)
Yes	Yes	119.5	0.15
No	Yes	119	0.2
Yes	No	172.6	0.5
No	No	185.8	0.5

Table One: Rate Measurement Data for Test Stand

between the counters in Figure Three. As is evident here, the ratio increases as the rate drops, and an ideal counter plane separation will be one that achieves a balance between the two. In any case, we have found that since the planes cannot be separated by more than about seven meters, the percentage of muons through the top and bottom planes that will actually go through the TPC can be at its highest about 53%.

In terms of the rates of muons crossing through the counters, our results are summarized in Table One. (Note that the data here are not supposed to reflect the rates in Figure Three. Figure Three displays the estimates for the configuration used in the 35 Ton Prototype, whereas spacial restrictions at the testing site forced us to use a counter configuration of different dimensions.) Here, our theoretical estimates put the muon rate through our configuration at around 175 Hz. The top two rows in the chart do not match this well, each row deviating by about 31% of the predicted value. However, since these two columns employ a logical exclusive “or” between the counters in each plane, this condition can potentially exclude muons that accompany a cosmic shower. The rates measured with a logical normal “or” approach the theoretical estimates, with a much smaller error between 1% and 6% of the theoretical value.

The difference between the rates for a given logic “or” did not significantly vary much. For the exclusive “or” setting, the rates were practically identical, which suggests that there isn’t much use in the second layer of counters on the top plane. For the normal “or” logic setting, the values differed by a slightly greater amount, or about 8%. This may just be due to random fluctuation. Another explanation for seeing this discrepancy where there appeared to be none for the exclusive “or” setting could be the fact that the exclusive “or”, even without the top two layers in coincidence, prevented cosmic shower particles from contributing to the final count. In the normal “or” case, setting the top two layers in coincidence would reduce the frequency of a cosmic shower coinciding with a random hit on the bottom counter plane to successfully register a count. However, without the top plane’s multi-layer coincidence, the normal “or” case would more easily permit these false counts, and for this reason, there could be a slight gap between the two coincidence conditions for the normal “or” logic setting. In spite of this distinct difference in the rates, the differences are all quite small, leading us to think that a second layer of counters on one of the planes is not crucial to our work.